



Electromagnetic Aluminum Levitator

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TOOLS:

- [Awl \(1\)](#)
- [Drill \(1\)](#)
- [Hacksaw \(1\)](#)
- [Knife \(1\)](#)
- [Multimeter \(1\)](#)
[that measures down to 1/100Ω](#)
- [Screwdriver \(1\)](#)
- [Soldering tools \(1\)](#)



PARTS:

- [Lumber \(1\)](#)
- [Magnet wire \(1\)](#)
*[Mouser Electronics #566-8075](#)
<http://mouser.com>*
- [Rod \(1\)](#)
[I used a cold-rolled steel rod, but purified iron would work best.](#)
- [Tubing \(1\)](#)
*[Hardware stores sell this, but I cut mine from the handle of an old snow rake I used before global warming set in.](#)
[Fishing and pool nets also frequently use aluminum tubing, and check out yard and garage sales for other sources of cheap aluminum tubing.](#)*
- [Power strip \(1\)](#)
[UL listed and rated at 12A or more](#)
- [Fuse holder \(1\)](#)

[RadioShack #270-739](#)

[\(http://radioshack.com\)](http://radioshack.com)

- [Plywood \(2\)](#)
[or similar material. I used scrap epoxy-glass printed circuit boards \(PCBs\).](#)
- [Fuses \(1\)](#)
[It helps to have some spares handy.](#)
- [Extension power cord \(1\)](#)
[rated at 13A or more](#)
- [Wire \(1\)](#)
- [Hose clamp \(1\)](#)
- [Tape \(1\)](#)
- [Epoxy cement \(1\)](#)
- [Wood screws \(4\)](#)
- [Tape \(1\)](#)
- [Heat-shrink tubing \(1\)](#)

SUMMARY

About 13 years ago I learned of some military research into a satellite- and missile-defense device that would propel projectiles using Lenz's law, which governs the direction of electrical current induced by a changing magnetic field. I decided to make a little gadget based on the same principle for my kids, to get them interested in science and electronics. The gadget worked — both at levitating and shooting rings, and at interesting my kids (some of them, anyway).

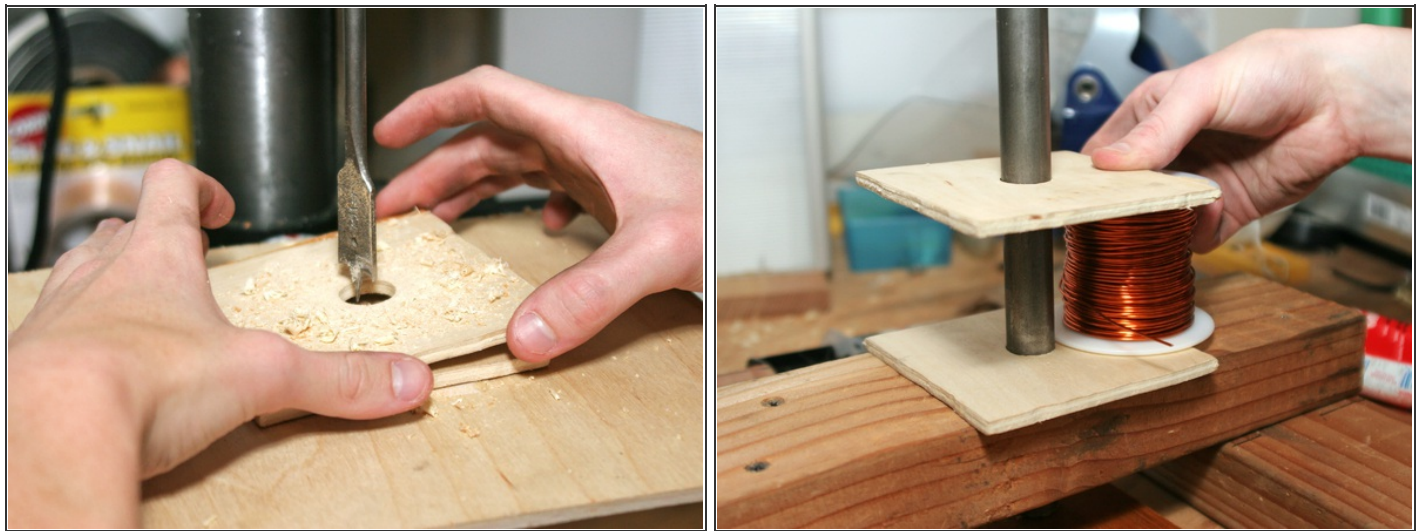
This design is actually the third one I tried. I had no real information on what the military was up to, so I tested my own ideas. One iteration used wire wound around a steel pipe with a short piece of aluminum rod inside. (That one didn't work — trust me!)

Not only is this project physically exciting and intellectually stimulating, it's also quick, easy, and inexpensive to build. Except for the 200 feet of #18 magnet wire, you can purchase everything you need at a hardware store or scavenge it from common junk.

Step 1 — Make the stand.



- Cut the 2×4 into three 1' lengths. Drill a $\frac{3}{4}$ " hole centered through one of them.
- Attach the $\frac{3}{4}$ " drilled wood piece crosswise over the other 2 pieces to make an "H" shape. First, mark and drill two $1\frac{1}{64}$ " holes staggered at each end of the center piece using a countersink (see 3rd picture at left).
- Next, with an awl or thin pencil, mark pilot hole locations on the middles of the other pieces through the countersunk holes. Drill $\frac{5}{64}$ " pilot holes, line them up with the holes on the center piece, and screw the stand together with four $2\frac{1}{2}$ " #8 screws.

Step 2 — Wind the coil.

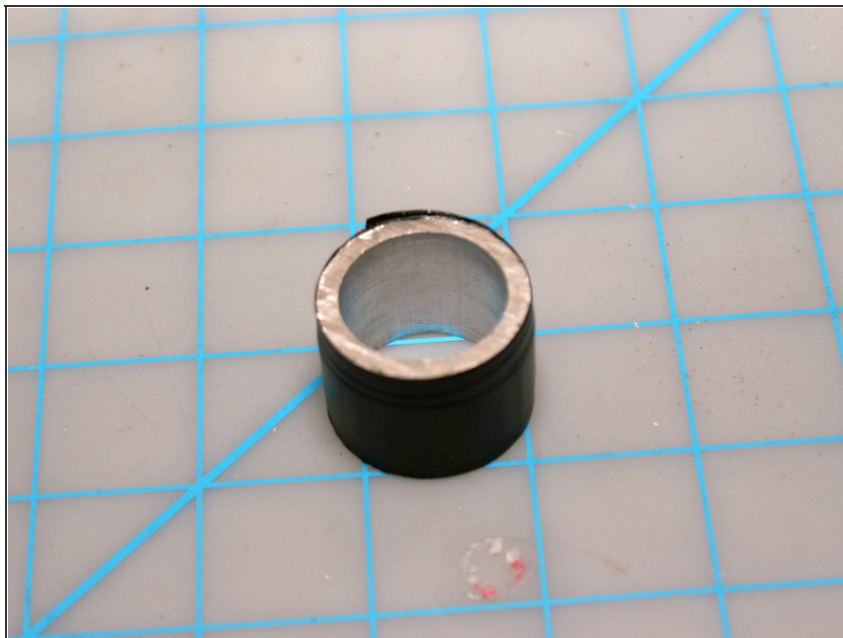
- Cut the plywood or PCB material into two 4" squares and drill a $\frac{3}{4}$ " hole in the center of each.
- Jam the 2'–3' metal rod through the hole in the stand so it protrudes 1" from the bottom, and slide one of the 4" squares down the rod from the top, resting it on the stand (about 3" from the end of the rod).
- Use epoxy to cement the square in place on the rod — then, using your wire spool for spacing and temporary support, slide the second 4" square onto the rod and epoxy it in place, about 2½" up from the first. Let the epoxy cure.

Step 3

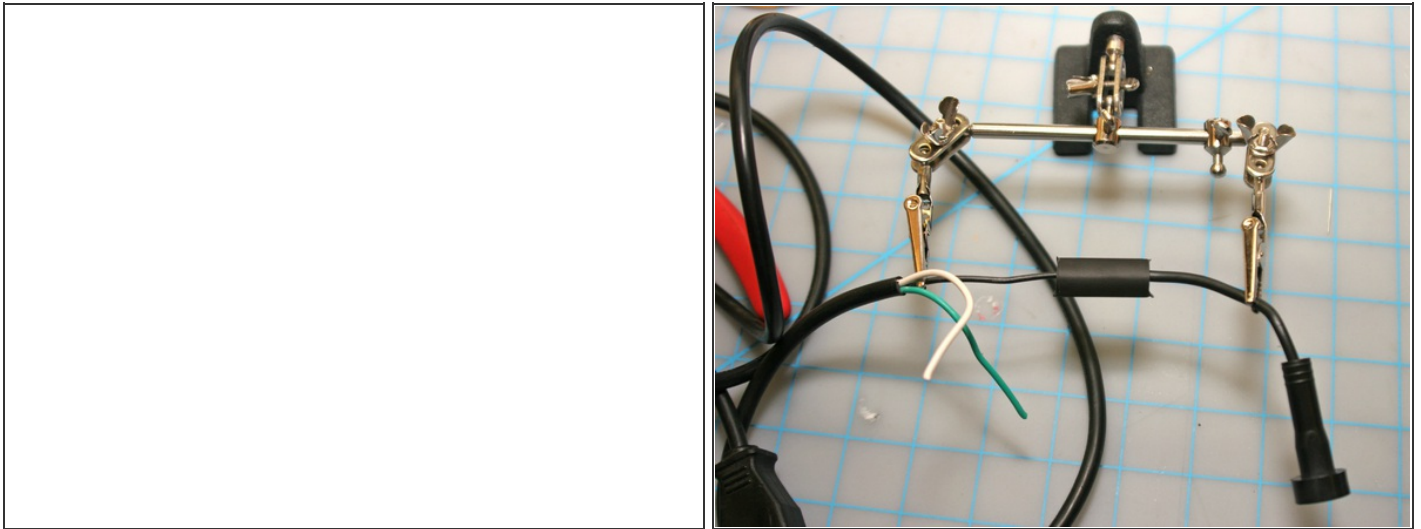


- Wrap electrical tape around the rod to completely cover the area between the 2 squares. This adds extra insulation between the coil and rod, for safety.
- Leaving 2"–3" of length free at the start and finish of the coil, tightly wind the full spool of #18 magnet wire (approximately 200') around the rod between the 2 squares. These lengths of wire will connect the coil to the 120V AC power source later. Once the coil is done, use electrical tape to prevent the wire from unraveling.

Step 4 — Cut the rings.

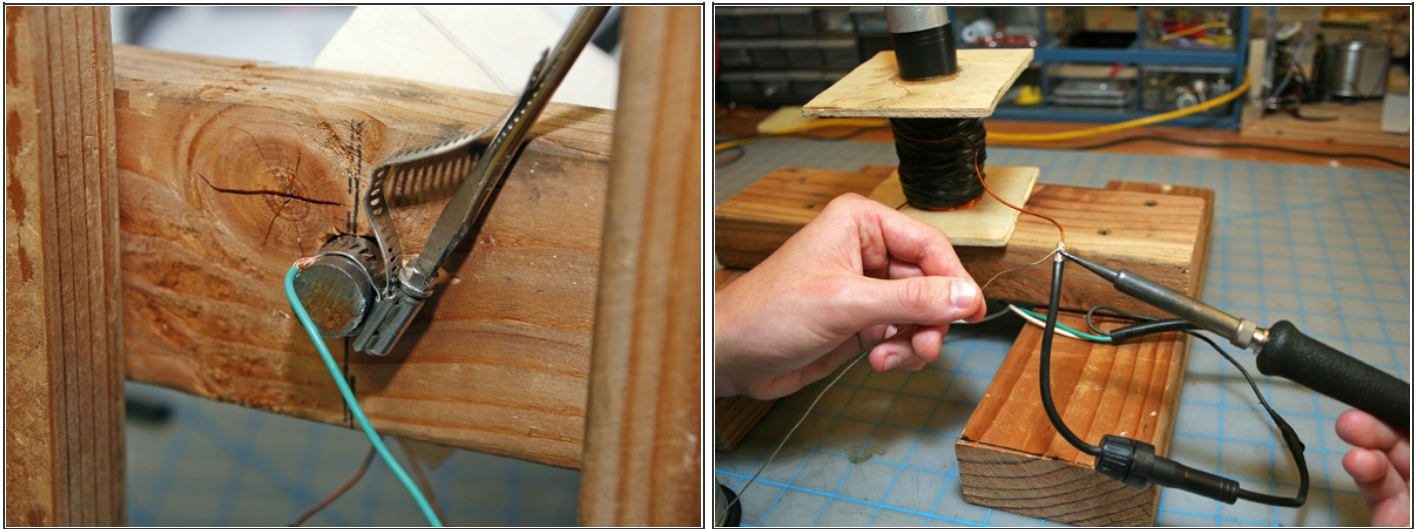


- Use a hacksaw or similar tool to cut several rings from the aluminum tubing. They should be at least 1" long, but you can cut different sizes to experiment. You'll need a whole bunch; the rings can shoot up so high that you might lose some!
- You can try cutting rings from other materials, although steel or iron tubing won't work well because it's not only heavier and has a lower electrical conductivity than aluminum, it's also inherently magnetic and will be attracted to the coil during those 2 instances in every cycle when the voltage isn't changing.
- Copper tubing conducts electricity even better than aluminum, but it's also heavier than aluminum and doesn't react physically (due to inertia) as strongly to the changing magnetic field as aluminum.
- Rings cut from any type of tubing should have an inside diameter of 13/16"–1".
- **Optional:** To make the rings easier to see and photograph, wrap the outsides with brightly colored tape.

Step 5 — Wire it together.

- This project has only 3 electrical parts: the plug (P1 in the schematic at right), the coil (L1), and the fuse (F1). The time-delay 7A fuse is required to keep the coil from heating to possibly dangerous levels if you leave the power-strip switch on.
- Use a knife or sandpaper to scrape 1" of enamel insulation off each end of the coil's magnet wire.
- Cut off the socket end of the heavy-duty power cord, and strip ½" of insulation from each of its 3 wires. Use a multimeter to confirm that the wires are color-coded correctly: with the cord's plug pointing away from you, and with the round prong (ground) at the bottom, the white wire should connect to the left, usually larger (neutral) flat tab; the black or brown wire to the right, usually smaller (hot) flat tab; and the green wire to ground.
- Solder the cord's hot (black/brown) wire to one side of the fuse holder, and solder the neutral (white) wire to one end of the coil. Use heat-shrink tubing or electrical tape to insulate this and all other solder connections.

Step 6



- To ground the metal rod, strip an additional 3" of insulation off the green wire, wrap it around the bottom of the rod, and secure it with a hose clamp. If the rod is corroded, sand or scrape the contact area first to ensure a good connection.
- Solder a short length of #14 or #16 insulated wire to connect the free end of the coil to the free end of the fuse holder.

Step 7 — Preliminary testing.



- Connect the multimeter's leads to measure resistance between the 2 flat tabs (hot and neutral) on the plug end of the power cord. It should measure between 1.1Ω and 2Ω .
- Leave one test lead connected to its tab and apply the other one to the center ground prong; it should register infinite ohms, no connection. Move the ground probe from the prong and touch it to the outside of the coil (the wire's enamel coating) and the metal rod. It should measure infinite ohms for both of these.
- If the multimeter detects any conductivity (less than infinite ohms), **DO NOT apply power to the device until the problem has been resolved.** 
- To make sure the rod is grounded, use the multimeter to check continuity from the plug's ground prong to the metal rod. If this checks out too, you're done!
- **SAFETY WARNING:** The rod must be grounded! This  ensures that the circuit breaker will trip if there's a short through any insulation, and that touching the rod won't cause a shock.

Plugging In

First, make sure any outlet you plug the power strip into is properly grounded. Test the AC voltage between the smaller, right (hot) slot and the bottom, rounded (ground) slot. It should read 110V–120V AC. If it's outdoors, the outlet must be a UL-listed GFCI (ground-fault circuit interrupter) type. These outlets have test and reset buttons, and are often used where moisture might cause short circuits.

CAUTION: When setting up, place the stand a healthy distance away from the switch-operated power strip. This is why you used an extension cord at least 15' long. Also, place the stand on a high table or other flat, raised surface so that no one can look down over the rod and accidentally get hit in the eye.

Floating and Flying

To make the ring levitate, switch the power strip on first, then immediately slip the ring over the rod using one hand (keep the other behind your back). This is easier with 2 people (and safer and more fun). Notice that the ring stops and hovers instead of falling. The ring is levitating! Then shut off the power immediately, or else the fuse will blow within a few seconds and need to be replaced.

For more fun, try shooting the ring upward. For safety's sake in your first attempt, wrap the ring with 2 layers of electrical tape. This will weigh it down so it won't shoot very high. Put the ring on the rod and let it slide down to the coil. Step back about 10', then turn on the power strip. The ring should shoot up enough to come off the rod. If you want it to go higher, remove some or all of the ring's tape.

Faster and Higher!

This is a demonstration project. While its operation is impressive, you can shoot the ring higher and faster if you make a few changes. For all these enhancements, the most important precaution is to locate the coil and rod even farther away from the switch, yourself, and any observers. To do this, use a 50' extension cord in the build, or add it in between the power strip and the levitator plug. Any enhancements are for shooting only — not the levitating trick. No one should get close to the live rod.

One improvement is to use a rod made from special purified iron instead of the cold-rolled steel rod. Second, you can try using heavier-walled aluminum for the ring, and experiment with different lengths. Third, you can make a larger coil with more turns.

With any such “enhanced levitator,” make sure you take the same precautions used by model rocket hobbyists. Following are some rules adapted from the National Association of Rocketry’s safety code (<http://nar.org/NARmrsc.html>).

Use a countdown before launch, and make sure any guests are paying attention and are a safe distance away at the time of launch. Place the levitator on a table or platform, and aim the rod close to vertical (within 30°). Never point the rod at anyone! Test the levitator first outside in an open area that exceeds a 50' radius. Locate it at a safe distance from overhead power lines.

You may notice that the ring shoots up faster at times, with the least impressive performances generally occurring while you’re showing someone you want to impress. The difference in heights depends on the instantaneous AC voltage, which in a typical house can vary from below 110V up to 120V.

SAFETY WARNING: Do not try to shoot the ring to the moon by hooking the coil up to a voltage source higher than 120V AC. For example, do not try this project with 240V AC. Even if the magnet wire’s insulation holds up, you can start a fire or cause serious injury. Leave higher-voltage experimentation to the military or MythBusters!

This project first appeared in [MAKE Volume 24](#), page 100.

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